Supplementary material

# Forest data

This material covers data and GIS operations to arrive at the point layer and its further processing into stands. The original data forms the basis for creating a point layer with each point covering 12.5x12.5 m that is consistent with the original pixel data. Specific numbers refer to 10 areas representing Kronoberg County (Figure 1). They have a total area of 89,156 ha and a forest area of 59,593 ha representing 10.5% and 9.1% of the total and forest area of Kronoberg respectively, i.e. the forest is marginally less extensive in the 10 areas compared to Kronoberg as a whole.

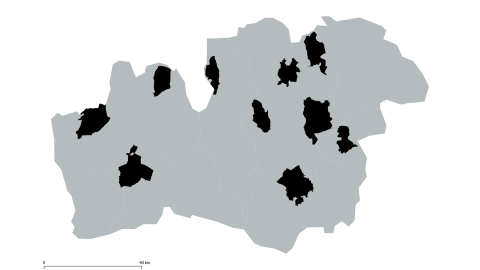


Figure 1. The location of the 10 areas representing Kronoberg County.

## Basic data

Table 1. Original GIS information. All original data is from Swedish Forest Agency (2018) if nothing else is stated.

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| --- |
| Data with pixel origin |
| Basal area (m2 ha-1) |
| Volume of pine trees (m3 ha-1) |
| Volume of spruce trees (m3 ha-1) |
| Volume of deciduous trees (m3 ha-1) |
| Average height, basal area weighted (dm) |
| Average diameter, basal area weighted (cm) |
| Soil moisture (topographic wetness index - TWI)(1) |
| Data with vector or polygon origin |
| Year of notification of final harvest (year) |
| Cadastral unit number (no.)(2) |
| Stand type, code used in ‘Marktäckedata’ (3) |
| Nature protection status (various layers on protection and agreements) |
| Streams and lakes (2) |

(1) Curtesy of William Lidberg, Department of Forest Ecology and Management, SLU, providing the TWI data.

(2) Lantmäteriet 2018.

(3) Metria 2018.

Comments on the processing of the original data:

* Owner ID was assigned to each point by linking cadastral number with owner ID(\*) gives a common number for all cadastral units owned by the same owner.
* Year of notification of final harvest is used to identify points that are barren (height 0 and few years since notification) and points that have zero height but more time from notification and is assigned height, basal area and species based on a regression on NFI plots.
* Volume is not used as is, instead it is used to derive the relative share of each species/species group (volumes are all computed in the Heuerka system).
* Soil moisture TWI data is converted to classes dry, mesic, mesicmoist, moist, and wet by setting breakpoints such that the distribution of area on classes coincide as close as possible with NFI data for Kronoberg.

(\*) Curtesy of David Alger, department of Forest Resource Management, SLU, providing the data register.

## Stand delimitation

Stands are delimited within sections. A section is defined as a contiguous area that has the same owner, is either formally protected or not, and that does not cut across lakes, major roads, and streams (>6 m wide; smaller streams have no width registered and most of them can be passed by harvesting machinery).

The stand formation algorithm is done in two steps. In the first step a range of potential stand delimitation alternatives are created and in the second step the sum of within stand standard deviation is minimized. The first step uses a region growing method (see e.g. Grilli et al. 2017) to create alternative stands and the second step uses linear programming to combine the stand alternatives to a map of stands mapping the forest. The criteria used to guide the growth of each stand alternative and the measure of standard deviation in linear programming objective function is the first principal component of variables (factor loadings in parenthesis) height (-0.53), basal area (-0.56), and the relative volume shares of pine (-0.35), spruce (-0.14) and deciduous species (0.50) accounting for 47% of the variation. Thus, at one end you would find old or well stocked pine and spruce forests with large negative principal component values and at the other end you find barren land or young stands with predominantly deciduous forests with large positive values.

The algorithm was set for a minimum size of ½ ha and a maximum of 4 ha. However, due to “cleaning up” of pockets of unallocated points 23% of the area consists of stands larger than 4 ha, though none above 6.5 ha. The total number of stands is 50,721 with an average of 1.2 ha and median of 0.6 ha. Aggregation of point data to stand data is performed with the median function.

## Data for projecting stand development

The data of the stands are not used directly. Instead each stand is linked to an NFI plot and the projected development of this plot is used as data for the stand, i.e. an imputation method is applied. There are two reasons for that. Firstly, and the most important, the remote sensing data behind the stand data does not contain information on age and site index. Functions describing any of these variables are not available and tests of functions develop by the authors based on NFI data was discouraging. Secondly, making projections with the current growth simulator for each stand (for the 10 areas more than 50,000), would be computationally very demanding. A stand is linked to an NFI plot through the shortest Euclidean distance in a normalized space defined by the same variables used to define stands with the addition that the relative share of deciduous forest was differentiated on the sum of oak and beech and other deciduous species, respectively. The NFI plots are from Kronoberg and neighboring counties (Halland, Jönköping, Kalmar, Blekinge, Kristianstad) from the years 2008 to 2013 and count to 6,318 in total. When the stand is projected it will be turned into barren land once final harvest is simulated. Thus, each stand is, besides being linked to an NFI plot, linked to a barren land stand based on moisture (5 classes) and site index (6 classes). This also applies to stands that are barren already from the start of the simulation.

## Comparison of sampled area with NFI data for Kronoberg County

To verify that the procedures reflect conditions in Kronoberg County, a number of stand variables from the 10 areas were compared with the 1,334 NFI data plots for Kronoberg County inventoried 2008-2013, i.e. during the period when remote sensing data was acquired. The most conspicuous indication of a deviation is probably that that there is too much pine and too little of deciduous species (Figure 2). The deviation of the 10 area data from the NFI data for the site index class 30 m appears more to be a sampling error of the NFI data than a real misclassification of the 10 area data. Other distributions appear to follow similar trends for the two datasets. The average volume per ha is 144 m3 in both materials whereas the average age is 51 and 44 years in the 10 areas and NFI respectively.

|  |  |
| --- | --- |
| (a) | (b) |
|  |  |
| (c) | (d) |
|  |  |

Figure 2. The initial state for forest variables for the 10 areas and for the NFI data of Kronoberg County. (a) Species distribution in terms of average stocking ha-1. (b) Age class distribution based on area (age class designated with upper closed bound). (c) Site index in 2 m classes (designated with lower closed bound). (d) The average stocking in different age classes (age class designated with upper closed bound).

## Example of results

Several typical features can be observed in the cut-out area of 130 ha area in Figure 3. One feature is that there are several small properties cutting through the landscape. There are also signs that previous harvests in many cases follow the property boundaries. There are spots of darker grey in many of the white and light grey stands. This is most likely the retention trees that are left at the harvesting sites. Another feature is the heterogeneity of stand conditions, resulting in stand delimitations with an average size of 1.2 ha and a median of 0.6 ha. The heterogeneity, in addition to small properties, resulted in small final felling sites, often not more than 1 to 2 ha, which are in line with recent official statistics (average 2,1 ha in Kronoberg) (Swedish Forest Agency, 2018).

All GIS operations were done with FME (2018) and GIS based illustrations were produced with QGIS (2018).

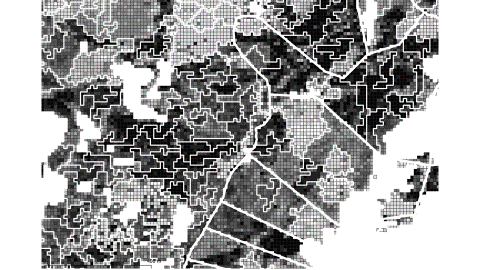


Figure 3. A 130 ha extract showing the resulting stand borders in white. Property borders are in thick white. Square point theme color is distributed on 10 classes with equal number of points in each class based on the principal component (PC) values (light corresponds to large positive PC values and dark corresponds to large negative values meaning that barren land is white and the most highly stocked stands are black).

## References

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